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Transmission Measurements (4000-400 cm^{-1} , 2.5-25 μm) of Crystalline Ferric Oxides and Ferric Oxyhydroxides: Implications for Mars; Ted L. Roush¹, James F. Bell III², and Richard V. Morris³,
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Ample evidence exists indicating abundant iron bearing minerals are present on Mars. In situ analyses performed by the Viking Landers were interpreted as indicating the presence of iron-rich materials, including iron oxides [1-5]. However, since the Viking Landers did not carry any instruments capable of determining mineralogy, the specific iron-bearing phases remains uncertain. Interpretations of continuing visual, near-, mid- and far-infrared spectroscopic observations of Mars from the Earth [e.g. 6,7] and spacecraft over the past 20 years [6-13] have revealed that the ferric mineralogy occurs in two distinct forms: (1) nanophase or truly amorphous Fe^{3+} -bearing materials [14,15] that spectrally resemble certain terrestrial palagonites [e.g. 16-20]; and (2) well-crystalline ferric oxides like hematite ($\alpha\text{-Fe}_2\text{O}_3$), maghemite ($\gamma\text{-Fe}_2\text{O}_3$), or magnetite (Fe_3O_4) [1,5,15, 21-24]. The available data indicate that the poorly-crystalline "palagonite-like" phases are spectrally dominant [e.g. 6,7] and that the well crystalline ferric oxides cannot constitute an abundance of more than about 4-8 wt. % [24]. Information regarding the crystalline or amorphous nature of the iron-bearing (and other) surface materials on Mars can provide insight into the availability of liquid water at the surface and the duration, mode, and extent of weathering. The research presented here represents the initial phase of a broader project that is intended to provide data in the mid- and far infrared spectral region for both well-characterized iron oxides/oxyhydroxides and poorly crystalline or amorphous materials (e.g. palagonites). Such information can be useful in the interpretation of both past and future thermal infrared observations of Mars.

In the near- to middle infrared (2.5-25 μm), spectral features arise from vibrational motions of atoms and molecules which compose the materials. These fundamental modes are much more intense than any associated combination and/or overtones of these modes, and hence remote sensing in the infrared is extremely sensitive to minor concentrations of these absorbing species [25].

We have measured the transmission spectra of three ferric oxides (2 $\alpha\text{-Fe}_2\text{O}_3$ samples, and 1 $\gamma\text{-Fe}_2\text{O}_3$ sample) and two ferric oxyhydroxides ($\alpha\text{-FeOOH}$ and $\gamma\text{-FeOOH}$). The physical and chemical properties of these samples have been previously reported along with measurements of their reflectance in the 0.3- to 2.1 μm spectral region [21]. A small amount (approx. 1 mg) of each sample was mixed with KBr powder while both were immersed in alcohol. After the alcohol evaporated, 200 mg of the resultant mixture was pressed into a cohesive pellet using a standard 13 mm KBr pellet die. Using the facilities at the NASA Ames Astrochemical Laboratory, with the cooperation of Drs. Robert Bohn, Scott Sandford and Louis Allamandola, the transmission of each pellet was measured at a resolution of 4 cm^{-1} using a Nicolet 7199 Fourier transform spectrometer in the 4000 to 400 cm^{-1} spectral domain, and was subsequently ratioed to the transmission of a pure KBr pellet. The resulting measurements of the ferric oxides are shown in figure 1 and of the ferric oxyhydroxides in figure 2.

Transmission spectra of both hematites exhibit strong absorptions with minima located at ≈ 18.3 and 20.9 μm separated by a maximum near 20 μm . All are consistent with previous measurements [26,27,28]. Additional transmission minima occur near 2.9, 6.1, 7.1, 8.8, 9.5, 11.4, and 17.3 μm for HMS3. The transmission spectrum of $\gamma\text{-Fe}_2\text{O}_3$ exhibits several minima located near 14.4, 15.7, 18.2, 20.8, 22.7, and 23.7 μm , and several weaker features located near the same positions as those of HMS3.

The transmission spectrum of $\alpha\text{-FeOOH}$ exhibits minima located near 3.2, 5.6, 6, 8.8, 11, 12.5, 16.6, 21.2, and 23.6 μm , and a hint of a feature near 15 μm that is obscured by imperfect correction for atmospheric CO_2 . All of these, except the 5.6 μm band, are comparable to previously reported features [26,29,30]. The transmission spectrum of $\gamma\text{-FeOOH}$ exhibits minima located near 3.2, 5.0, 6, 8.6, 9.8, 13.3, 16.8, 18.9, 20.8, and 23.9 μm . The bands at 3.2, 8., 9.8, 1.8, 18.9, and 23.9 μm are

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similar to bands previously reported [29].

This preliminary study has demonstrated that crystalline ferric oxides and ferric oxyhydroxides exhibit complex spectral features at thermal wavelengths. Some of these features suggest that thermal infrared observations of Mars can provide significant insight into the ferric mineralogy of that planet. The results of this study suggest that emissivity spectra of crystalline ferric oxides and ferric oxyhydroxides may prove quite important for the interpretation of thermal infrared spectral observations of Mars.

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